

ANALYSIS OF THE VERTEXES $\Omega_Q^* \Omega_Q^* \phi$, $\Omega_Q^* \Xi_Q^* K^*$, $\Xi_Q^* \Sigma_Q^* K^*$ AND $\Sigma_Q^* \Sigma_Q^* \rho$ WITH THE LIGHT-CONE QCD SUM RULES

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Abstract

In this article, we parameterize the vertexes $\Omega_Q^* \Omega_Q^* \phi$, $\Omega_Q^* \Xi_Q^* K^*$, $\Xi_Q^* \Sigma_Q^* K^*$ and $\Sigma_Q^* \Sigma_Q^* \rho$ with four tensor structures due to Lorentz invariance, and study the corresponding four strong coupling constants with the light-cone QCD sum rules.

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1 Introduction

The charmed and bottom baryon states which contain a heavy quark and two light quarks are particularly interesting for studying the dynamics of the light quarks in the presence of a heavy quark. They serve as an excellent ground for testing predictions of the quark models and heavy quark symmetry [1, 2]. The mass spectrum and magnetic moments of the heavy (and doubly heavy) baryon states have been studied by a number of the theoretical approaches [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. Among those theoretical approaches, the QCD sum rules and light-cone QCD sum rules are powerful tools in studying the ground state heavy baryons and have given many successful descriptions of the properties [16, 17, 18, 19, 20, 21].

In Refs.[22, 23], we study the strong coupling constants in the vertexes $\Omega_Q^* \Omega_Q \phi$, $\Xi_Q^* \Xi_Q' V$ and $\Sigma_Q^* \Sigma_Q V$ with the light-cone QCD sum rules, then assume the vector meson dominance of the intermediate $\phi(1020)$, $\rho(770)$ and $\omega(782)$, and calculate the radiative decays $\Omega_Q^* \rightarrow \Omega_Q \gamma$, $\Xi_Q^* \rightarrow \Xi_Q' \gamma$ and $\Sigma_Q^* \rightarrow \Sigma_Q \gamma$. In Refs.[24, 25], the strong coupling constants $g_{\Xi_Q \Xi_Q' \pi}$ and $g_{\Sigma_Q \Lambda_Q \pi}$ are calculated using the light-cone QCD sum rules. In this article, we analyze the vertexes $\Omega_Q^* \Omega_Q^* \phi$, $\Omega_Q^* \Xi_Q^* K^*$, $\Xi_Q^* \Sigma_Q^* K^*$ and $\Sigma_Q^* \Sigma_Q^* \rho$, which are of great phenomenological importance, and study the corresponding strong coupling constants with the light-cone QCD sum rules.

The baryon resonances can be classified as genuine qqq states (or large- N_c ground states) and molecule-like states generated dynamically, and the two-pole nature of the $\Lambda(1405)$ with $I(J^P) = 0(\frac{1}{2}^-)$ serves as an excellent support for the hadrogenesis conjecture [26]. The negative-parity baryon resonances (some are supposed to be molecule-like states) can be studied through the meson-baryon scatterings in the coupled-channel unitary schemes, where the tree-level scattering kernels are derived from the $SU(3)$ chiral lagrangian [27], the flavor-spin $SU(6)$ extension of the Weinberg-Tomozawa meson-baryon interactions [28], the t -channel vector meson exchange model based on the flavor $SU(4)$ symmetry combined with the chiral symmetry [29, 30], the flavor-spin $SU(8)$ extension of the Weinberg-Tomozawa meson-baryon interactions [31], the flavor $SU(4)$ t -channel vector meson exchange model [32], etc. In the limit $t \rightarrow 0$, the vector meson exchange models and the Weinberg-Tomozawa interactions result in analogous scattering kernels, where the strong coupling constants in the vertexes BBV , B^*BV and B^*B^*V play an important role, for example, the strong coupling constant in the vertex $\Omega_c^* \Omega_c^* \phi$ for the t -channel $\phi(1020)$ -exchange induced scattering $\Omega_c^* + D_s \rightarrow \Omega_c^* + D_s$. In the real world, the flavor $SU(4)$ and the spin $SU(2)$ are (badly) broken, an universal coupling constant is not a good approximation, we should calculate those coupling constants in different channels independently to estimate the symmetry breaking effects.

In recent years, the Babar, Belle, CLEO, D0, CDF and FOCUS collaborations have discovered (or confirmed) a number of new heavy baryon states [33, 34], and some states have been studied in the coupled-channel unitary schemes, for example, the $\Lambda_c(2595)$ is tentatively identified as a D^*N

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or DN molecular state [31, 35, 36]. The coupled-channel unitary approaches have predicted many heavy baryon resonances, which maybe discovered at the LHCb, RHIC, PANDA, etc, we should study the strong coupling constants in the vertexes BBV , B^*BV and B^*B^*V in great details to make the predictions more reliable.

The article is arranged as follows: we derive the strong coupling constants in the vertexes B^*B^*V with the light-cone QCD sum rules in Sect.2; in Sect.3, we present the numerical results and discussions; and Sect.4 is reserved for our conclusions.

2 The vertexes B^*B^*V with light-cone QCD sum rules

We parameterize the vertexes B^*B^*V with four tensor structures due to Lorentz invariance and introduce four strong coupling constants g_1 , g_2 , g_3 and g_4 [37, 38],

$$\begin{aligned} \langle B_i^*(p+q)|B_j^*(p)V(q)\rangle &= \bar{U}_i^\alpha(p+q) \left\{ \left[g_1 g_{\alpha\beta} + g_3 \frac{q_\alpha q_\beta}{(M_i + M_j)^2} \right] \not{\epsilon} \right. \\ &\quad \left. - \left[g_2 \frac{g_{\alpha\beta}}{M_i + M_j} + g_4 \frac{q_\alpha q_\beta}{(M_i + M_j)^3} \right] \not{\epsilon} \not{q} \right\} U_j^\beta(p), \end{aligned} \quad (1)$$

where the $U_\mu^i(p)$ is the Rarita-Schwinger spinor of the heavy baryon states B_i^* (Ω_Q^* , Ξ_Q^* , Σ_Q^*), the ϵ_μ is the polarization vector of the vector mesons V ($\phi(1020)$, $K^*(892)$, $\rho(770)$).

In the following, we write down the two-point correlation functions $\Pi_{ijV}(p, q)$,

$$\Pi_{ijV}(p, q) = w^\mu z^\nu i \int d^4x e^{-ip \cdot x} \langle 0 | T \{ J_\mu^i(0) \bar{J}_\nu^j(x) \} | V(q) \rangle, \quad (2)$$

$$\begin{aligned} J_\mu^\Omega(x) &= \epsilon^{abc} s_a^T(x) C \gamma_\mu s_b(x) Q_c(x), \\ J_\mu^\Xi(x) &= \epsilon^{abc} q_a^T(x) C \gamma_\mu s_b(x) Q_c(x), \\ J_\mu^\Sigma(x) &= \epsilon^{abc} q_a^T(x) C \gamma_\mu q'_b(x) Q_c(x), \end{aligned} \quad (3)$$

where $Q = c, b$ and $q, q' = u, d$, the a, b, c are color indexes, the Ioffe-type heavy baryon currents $J_\mu^\Omega(x)$, $J_\mu^\Xi(x)$, $J_\mu^\Sigma(x)$ interpolate the $\frac{3}{2}^+$ heavy baryon states Ω_Q^* , Ξ_Q^* , Σ_Q^* , respectively, the external vector mesons have the four momentum q_μ with $q^2 = m_{\phi/K^*/\rho}^2$.

We can insert a complete set of intermediate hadronic states with the same quantum numbers as the current operators $J_\mu(x)$ into the correlation functions $\Pi_{ijV}(p, q)$ to obtain the hadronic representation. After isolating the ground state contributions from the pole terms of the heavy baryons Ω_Q^* , Ξ_Q^* , Σ_Q^* , we get the following results,

$$\begin{aligned} \Pi_{ijV}(p, q) &= \frac{\langle 0 | w \cdot J_i(0) | B_i^*(q+p) \rangle \langle B_i^*(q+p) | B_j^*(p) V(q) \rangle \langle B_j^*(p) | z \cdot \bar{J}_j(0) | 0 \rangle}{[M_i^2 - (q+p)^2] [M_j^2 - p^2]} + \dots \\ &= \frac{\lambda_i \lambda_j}{[M_i^2 - (q+p)^2] [M_j^2 - p^2]} [\tilde{g}_1 \not{p} \cdot \epsilon w \cdot z + \tilde{g}_2 \not{p} \not{q} \cdot \epsilon w \cdot z \\ &\quad + \tilde{g}_3 \not{p} \cdot \epsilon q \cdot w q \cdot z + \tilde{g}_4 \not{p} \cdot \epsilon q \cdot w q \cdot z + \dots] + \dots, \end{aligned} \quad (4)$$

where the following definitions have been used,

$$\begin{aligned} \langle 0 | J_\mu^i(0) | B_i^*(p) \rangle &= \lambda_i U_\mu^i(p, s), \\ \sum_s U_\mu^i(p, s) \bar{U}_\nu^i(p, s) &= -(\not{p} + M_i) \left(g_{\mu\nu} - \frac{\gamma_\mu \gamma_\nu}{3} - \frac{2p_\mu p_\nu}{3M_i^2} + \frac{p_\mu \gamma_\nu - p_\nu \gamma_\mu}{3M_i} \right), \end{aligned}$$

$$\begin{aligned}
\tilde{g}_1 &= 2g_1, \\
\tilde{g}_2 &= \frac{2g_2}{M_i + M_j}, \\
\tilde{g}_3 &= -\frac{4g_1}{3M_i^2} + \frac{4g_2}{3M_i(M_i + M_j)} + \frac{g_3}{(M_i + M_j)^2} \left[2 - \frac{2(M_i^2 - M_j^2)}{3M_i^2} - \frac{2m_V^2}{3M_i^2} \right] \\
&\quad + \frac{2m_V^2 g_4}{3M_i(M_i + M_j)^3}, \\
\tilde{g}_4 &= -\frac{4g_1}{3M_i^2} - \frac{4g_2}{3M_i(M_i + M_j)} + \frac{g_3}{(M_i + M_j)^2} \left[\frac{4}{3} - \frac{2(M_i^2 - M_j^2)}{3M_i^2} - \frac{2m_V^2}{3M_i^2} \right] \\
&\quad + \frac{g_4}{(M_i + M_j)^3} \left[2M_i - \frac{4(M_i^2 - M_j^2)}{3M_i} - \frac{2m_V^2}{3M_i} \right]. \tag{5}
\end{aligned}$$

In calculation, we have ordered the Dirac matrixes as $\not{p} \not{p} \not{q} \not{q}$ [39].

The current $J_\mu(x)$ couples not only to the spin-parity $J^P = \frac{3}{2}^+$ states, but also to the spin-parity $J^P = \frac{1}{2}^-$ states. For a generic $\frac{1}{2}^-$ resonance B_Q , $\langle 0|J_\mu(0)|B_Q(p)\rangle = \lambda_*(\gamma_\mu - 4\frac{p_\mu}{M_*})U^*(p, s)$, where λ_* is the pole residue, M_* is the mass, and the spinor $U^*(p, s)$ satisfies the usual Dirac equation $(\not{p} - M_*)U^*(p) = 0$. In this article, we choose the tensor structures $\not{p} \not{p} \cdot \epsilon w \cdot z$, $\not{p} \not{q} \not{p} \cdot \epsilon w \cdot z$, $\not{p} \not{p} \cdot \epsilon q \cdot w q \cdot z$, $\not{q} \not{p} \cdot \epsilon q \cdot w q \cdot z$, the negative-parity baryon state B_Q has no contamination. For example, we can study the contribution of the $\frac{1}{2}^-$ baryon state B_Q to the correlation functions $\Pi_{ijV}(p, q)$,

$$\begin{aligned}
\Pi_{ijV}(p, q) &= \frac{\langle 0|w \cdot J_i(0)|B_i(q+p)\rangle \langle B_i(q+p)|B_j(p)V(q)\rangle \langle B_j(p)|z \cdot \bar{J}_j(0)|0\rangle}{[M_{*i}^2 - (q+p)^2][M_{*j}^2 - p^2]} + \dots \\
&= \lambda_{*i}\lambda_{*j} \left[\not{p} - 4\frac{(p+q) \cdot w}{M_{*i}} \right] \frac{\not{q} + \not{p} + M_{*i}}{M_{*i}^2 - (q+p)^2} \left[g_V \not{q} + i g_T \frac{\epsilon^\alpha \sigma_{\alpha\beta} q^\beta}{M_{*i} + M_{*j}} \right] \frac{\not{p} + M_{*j}}{M_{*j}^2 - p^2} \\
&\quad \left[\not{z} - 4\frac{p \cdot z}{M_{*j}} \right] + \dots, \\
&= 0 \not{p} \not{p} \cdot \epsilon w \cdot z + 0 \not{p} \not{q} \not{p} \cdot \epsilon w \cdot z + 0 \not{p} \not{p} \cdot \epsilon q \cdot w q \cdot z + 0 \not{q} \not{p} \cdot \epsilon q \cdot w q \cdot z + \dots, \tag{6}
\end{aligned}$$

where we introduce the strong coupling constants g_V and g_T to parameterize the vertexes $\langle B_i(q+p)|B_j(p)V(q)\rangle$, and order the Dirac matrixes as $\not{p} \not{p} \not{q} \not{q}$.

In the following, we briefly outline the operator product expansion for the correlation functions $\Pi_{ijV}(p, q)$ in perturbative QCD. The calculations are performed at the large space-like momentum regions $(q+p)^2 \ll 0$ and $p^2 \ll 0$, which correspond to the small light-cone distance $x^2 \approx 0$ required by the validity of the operator product expansion. We contract the quark fields in the correlation functions $\Pi_{ijV}(p, q)$ with Wick theorem,

$$\begin{aligned}
\Pi_{\Omega_Q^* \Omega_Q^* \phi}(p, q) &= 2i\epsilon^{ijk}\epsilon^{i'j'k'} \int d^4x e^{-ip \cdot x} S_Q^{kk'}(-x) \{ Tr [\not{p} \langle 0|s_j(0)\bar{s}_{j'}(x)|\phi(q)\rangle \not{z} C S_{ii'}^T(-x) C] \\
&\quad + Tr [\not{p} S_{jj'}(-x) \not{z} C \langle 0|s_i(0)\bar{s}_{i'}(x)|\phi(q)\rangle^T C] \}, \\
\Pi_{\Omega_Q^* \Xi_Q^* K^*}(p, q) &= 2i\epsilon^{ijk}\epsilon^{i'j'k'} \int d^4x e^{-ip \cdot x} S_Q^{kk'}(-x) Tr [\not{p} \langle 0|s_j(0)\bar{u}_{j'}(x)|K^*(q)\rangle \not{z} C S_{ii'}^T(-x) C], \\
\Pi_{\Xi_Q^* \Sigma_Q^* K^*}(p, q) &= 2i\epsilon^{ijk}\epsilon^{i'j'k'} \int d^4x e^{-ip \cdot x} S_Q^{kk'}(-x) Tr [\not{p} \langle 0|s_j(0)\bar{u}_{j'}(x)|K^*(q)\rangle \not{z} C U_{ii'}^T(-x) C], \\
\Pi_{\Sigma_Q^* \Sigma_Q^* \rho}(p, q) &= 2i\epsilon^{ijk}\epsilon^{i'j'k'} \int d^4x e^{-ip \cdot x} S_Q^{kk'}(-x) Tr [\not{p} \langle 0|d_j(0)\bar{u}_{j'}(x)|\rho(q)\rangle \not{z} C D_{ii'}^T(-x) C], \tag{7}
\end{aligned}$$

then perform the Fierz re-ordering to extract the contributions from the two-particle vector meson light-cone distribution amplitudes, substitute the full s , u , d and Q quark propagators ($S(x)$, $U(x)$),

$D(x)$ and $S_Q(x)$ into the correlation functions and complete the integrals in the coordinate space and momentum space sequentially, and obtain the correlation functions at the level of quark-gluon degree's of freedom. In calculation, the two-particle vector meson light-cone distribution amplitudes up to twist-4 have been used [40, 41, 42, 43]. The parameters in the light-cone distribution amplitudes are scale dependent and are estimated with the QCD sum rules [42, 43]. In this article, the energy scale μ is chosen to be $\mu = 1$ GeV.

Taking double Borel transform with respect to the variables $Q_1^2 = -p^2$ and $Q_2^2 = -(p+q)^2$ respectively, then subtracting the contributions from the high resonances and continuum states by introducing the threshold parameter s_0 (i.e. $M^{2n} \rightarrow \frac{1}{\Gamma[n]} \int_0^{s_0} ds s^{n-1} e^{-\frac{s}{M^2}}$), finally we can obtain 32 sum rules for the strong coupling constants $\tilde{g}_1, \tilde{g}_2, \tilde{g}_3$ and \tilde{g}_4 respectively, the explicit expressions are presented in the Appendix. In calculation, we neglect the contributions from the high dimension vacuum condensates, such as $\langle f_{abc} G^a G^b G^c \rangle$, $\langle \bar{q}q \rangle \langle \frac{\alpha_s G G}{\pi} \rangle$, $\langle \bar{s}s \rangle \langle \frac{\alpha_s G G}{\pi} \rangle$, etc. They are greatly suppressed by the large numerical denominators and additional inverse powers of the Borel parameter $\frac{1}{M^2}$, and would not play any significant roles.

3 Numerical result and discussion

The parameters which determine the vector meson light-cone distribution amplitudes are $f_\phi = (0.215 \pm 0.005)$ GeV, $f_\phi^\perp = (0.186 \pm 0.009)$ GeV, $a_1^\parallel = 0.0$, $a_1^\perp = 0.0$, $a_2^\parallel = 0.18 \pm 0.08$, $a_2^\perp = 0.14 \pm 0.07$, $\zeta_3^\parallel = 0.024 \pm 0.008$, $\tilde{\lambda}_3^\parallel = 0.0$, $\tilde{\omega}_3^\parallel = -0.045 \pm 0.015$, $\kappa_3^\parallel = 0.0$, $\omega_3^\parallel = 0.09 \pm 0.03$, $\lambda_3^\parallel = 0.0$, $\kappa_3^\perp = 0.0$, $\omega_3^\perp = 0.20 \pm 0.08$, $\lambda_3^\perp = 0.0$, $\zeta_4^\parallel = 0.00 \pm 0.02$, $\tilde{\omega}_4^\parallel = -0.02 \pm 0.01$, $\zeta_4^\perp = -0.01 \pm 0.03$, $\tilde{\zeta}_4^\perp = -0.03 \pm 0.04$, $\kappa_4^\parallel = 0.0$, $\kappa_4^\perp = 0.0$ for the ϕ -meson; $f_{K^*} = (0.220 \pm 0.005)$ GeV, $f_{K^*}^\perp = (0.185 \pm 0.009)$ GeV, $a_1^\parallel = 0.03 \pm 0.02$, $a_1^\perp = 0.04 \pm 0.03$, $a_2^\parallel = 0.11 \pm 0.09$, $a_2^\perp = 0.10 \pm 0.08$, $\zeta_3^\parallel = 0.023 \pm 0.008$, $\tilde{\lambda}_3^\parallel = 0.035 \pm 0.015$, $\tilde{\omega}_3^\parallel = -0.07 \pm 0.03$, $\kappa_3^\parallel = 0.000 \pm 0.001$, $\omega_3^\parallel = 0.10 \pm 0.04$, $\lambda_3^\parallel = -0.008 \pm 0.004$, $\kappa_3^\perp = 0.003 \pm 0.003$, $\omega_3^\perp = 0.3 \pm 0.1$, $\lambda_3^\perp = -0.025 \pm 0.020$, $\zeta_4^\parallel = 0.02 \pm 0.02$, $\tilde{\omega}_4^\parallel = -0.02 \pm 0.01$, $\zeta_4^\perp = -0.01 \pm 0.03$, $\tilde{\zeta}_4^\perp = -0.05 \pm 0.04$, $\kappa_4^\parallel = -0.025 \pm 0.005$, $\kappa_4^\perp = 0.013 \pm 0.005$ for the K^* -meson; and $f_\rho = (0.216 \pm 0.003)$ GeV, $f_\rho^\perp = (0.165 \pm 0.009)$ GeV, $a_1^\parallel = 0.0$, $a_1^\perp = 0.0$, $a_2^\parallel = 0.15 \pm 0.07$, $a_2^\perp = 0.14 \pm 0.06$, $\zeta_3^\parallel = 0.030 \pm 0.010$, $\tilde{\lambda}_3^\parallel = 0.0$, $\tilde{\omega}_3^\parallel = -0.09 \pm 0.03$, $\kappa_3^\parallel = 0.0$, $\omega_3^\parallel = 0.15 \pm 0.05$, $\lambda_3^\parallel = 0.0$, $\kappa_3^\perp = 0.0$, $\omega_3^\perp = 0.55 \pm 0.25$, $\lambda_3^\perp = 0.0$, $\zeta_4^\parallel = 0.07 \pm 0.03$, $\tilde{\omega}_4^\parallel = -0.03 \pm 0.01$, $\zeta_4^\perp = -0.03 \pm 0.05$, $\tilde{\zeta}_4^\perp = -0.08 \pm 0.05$, $\kappa_4^\parallel = 0.0$, and $\kappa_4^\perp = 0.0$ for the ρ -meson at the energy scale $\mu = 1$ GeV [42, 43].

The QCD input parameters are taken to be the standard values $m_s = (140 \pm 10)$ MeV = $24.6 m_{u/d}$, $m_c = (1.35 \pm 0.10)$ GeV, $m_b = (4.7 \pm 0.1)$ GeV, $\langle \bar{q}q \rangle = -(0.24 \pm 0.01 \text{ GeV})^3$, $\langle \bar{s}s \rangle = (0.8 \pm 0.2) \langle \bar{q}q \rangle$, $\langle \bar{s}g_s \sigma G s \rangle = m_0^2 \langle \bar{s}s \rangle$, $\langle \bar{q}g_s \sigma G q \rangle = m_0^2 \langle \bar{q}q \rangle$, $m_0^2 = (0.8 \pm 0.2) \text{ GeV}^2$, and $\langle \frac{\alpha_s G G}{\pi} \rangle = (0.33 \text{ GeV})^4$ at the energy scale $\mu = 1$ GeV [16, 17, 44].

The masses of the well established hadrons are taken from the Review of Particle Physics, $m_\phi = 1.019$ GeV, $m_{K^*} = 0.892$ GeV, $m_\rho = 0.775$ GeV, $M_{\Omega_c^*} = 2.766$ GeV, $M_{\Xi_c^*} = 2.646$ GeV, $M_{\Sigma_c^*} = 2.518$ GeV and $M_{\Sigma_b^*} = 5.833$ GeV [45]. The bottom baryon states Ξ_b^* and Ω_b^* have not been observed yet, we use the values from the conventional QCD sum rules, $M_{\Xi_b^*} = 6.02$ GeV and $M_{\Omega_b^*} = 6.17$ GeV [46]. The values of the pole residues λ_i are also determined with the conventional QCD sum rules, $\lambda_{\Omega_c^*} = (0.083 \pm 0.018) \text{ GeV}^3$, $\lambda_{\Xi_c^*} = (0.049 \pm 0.012) \text{ GeV}^3$, $\lambda_{\Sigma_c^*} = (0.038 \pm 0.011) \text{ GeV}^3$, $\lambda_{\Omega_b^*} = (0.056 \pm 0.012) \text{ GeV}^3$, $\lambda_{\Xi_b^*} = (0.033 \pm 0.008) \text{ GeV}^3$, $\lambda_{\Sigma_b^*} = (0.027 \pm 0.008) \text{ GeV}^3$ [46]. In the channels Σ_{Qqq}^* , we can make a simple replacement $\lambda_{\Sigma_Q^*} \rightarrow \sqrt{2} \lambda_{\Sigma_Q^*}$ to take into account the symmetry factor.

The threshold parameters s_0 and Borel parameters M^2 are taken as $s_0 = (12.0 \pm 1.0) \text{ GeV}^2$, $(12.0 \pm 1.0) \text{ GeV}^2$, $(11.5 \pm 1.0) \text{ GeV}^2$, $(11.0 \pm 1.0) \text{ GeV}^2$, $(47.0 \pm 1.0) \text{ GeV}^2$, $(47.0 \pm 1.0) \text{ GeV}^2$, $(46.0 \pm 1.0) \text{ GeV}^2$, $(45.0 \pm 1.0) \text{ GeV}^2$ and $M^2 = (2.4 - 3.4) \text{ GeV}^2$, $(2.3 - 3.3) \text{ GeV}^2$, $(2.1 - 3.1) \text{ GeV}^2$, $(2.0 - 3.0) \text{ GeV}^2$, $(5.3 - 6.3) \text{ GeV}^2$, $(5.2 - 6.2) \text{ GeV}^2$, $(4.8 - 5.8) \text{ GeV}^2$, $(4.6 - 5.6) \text{ GeV}^2$ for the strong

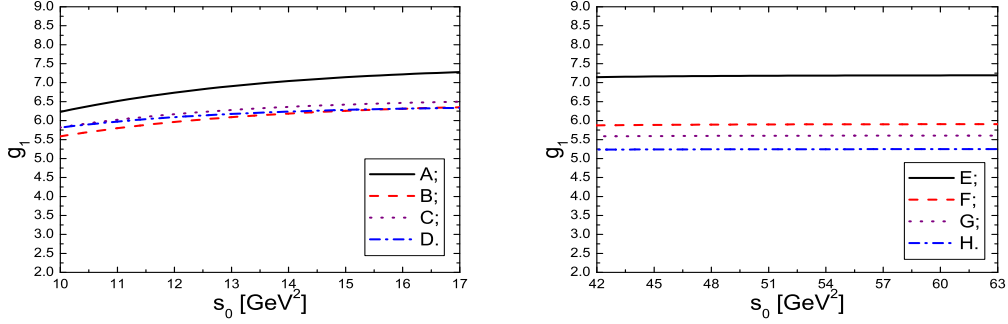


Figure 1: The values of the strong coupling constants g_1 with variation of the threshold parameter s_0 for the central values of the other parameters. The A , B , C , D , E , F , G and H denote the vertexes $\Omega_c^* \Omega_c^* \phi$, $\Omega_c^* \Xi_c^* K^*$, $\Xi_c^* \Sigma_c^* K^*$, $\Sigma_c^* \Sigma_c^* \rho$, $\Omega_b^* \Omega_b^* \phi$, $\Omega_b^* \Xi_b^* K^*$, $\Xi_b^* \Sigma_b^* K^*$ and $\Sigma_b^* \Sigma_b^* \rho$, respectively.

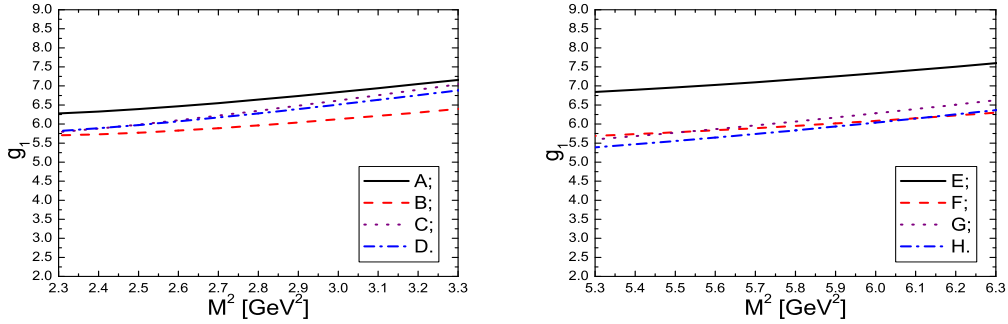


Figure 2: The values of the strong coupling constants g_1 with variation of the Borel parameter M^2 for the central values of the input parameters. The A , B , C , D , E , F , G and H denote the vertexes $\Omega_c^* \Omega_c^* \phi$, $\Omega_c^* \Xi_c^* K^*$, $\Xi_c^* \Sigma_c^* K^*$, $\Sigma_c^* \Sigma_c^* \rho$, $\Omega_b^* \Omega_b^* \phi$, $\Omega_b^* \Xi_b^* K^*$, $\Xi_b^* \Sigma_b^* K^*$ and $\Sigma_b^* \Sigma_b^* \rho$, respectively.

coupling constants in the vertexes $\Omega_c^* \Omega_c^* \phi$, $\Omega_c^* \Xi_c^* K^*$, $\Xi_c^* \Sigma_c^* K^*$, $\Sigma_c^* \Sigma_c^* \rho$, $\Omega_b^* \Omega_b^* \phi$, $\Omega_b^* \Xi_b^* K^*$, $\Xi_b^* \Sigma_b^* K^*$, $\Sigma_b^* \Sigma_b^* \rho$, respectively [46].

In Ref.[46], we study the masses and pole residues of the $\frac{3}{2}^+$ heavy baryon states with the conventional two-point QCD sum rules, and obtain the optimal Borel parameters M^2 and threshold parameters s_0 . The central values of the threshold parameters are $s_0 \approx (M_{B_i^*} + 0.7 \text{ GeV})^2$, which can take into account the ground state contributions sufficiently. In the constituent quark models, the energy gap between the ground states and the first radial excited states is about 0.5 GeV, the contributions from the high resonances and continuum states may be included in. The values of the strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 are not sensitive to the threshold parameters, the contaminations should be very small due to the suppression factor $e^{-x} < 4\%$ and $\ll 1\%$ in the charmed and bottom channels respectively, where $x = \frac{s_0}{M^2}$. In Fig.1, we plot the values of the strong coupling constants g_1 with variation of the threshold parameter s_0 for the central values of the other parameters to illustrate the fact. On the other hand, the values of the strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 are rather stable with variations of the Borel parameter, the uncertainties originate from the Borel parameters are not large. In Fig.2, we plot the values of the strong coupling constants g_1 with variation of the Borel parameter M^2 as an example. The Borel parameters and threshold parameters determined in Ref.[46] still work in the present case.

Taking into account all the uncertainties of the revelent parameters, finally we obtain the

Vertexes	g_1	$-g_2$	$-\tilde{g}_3(\text{GeV}^{-2})$	$-\tilde{g}_4(\text{GeV}^{-2})$
$\Omega_c^* \Omega_c^* \phi$	$6.80^{+3.84}_{-2.85}$	$0.036^{+0.035}_{-0.020}$	$2.50^{+2.06}_{-1.21}$	$1.24^{+1.03}_{-0.60}$
$\Omega_c^* \Xi_c^* K^*$	$6.05^{+3.45}_{-2.46}$	$0.034^{+0.034}_{-0.019}$	$9.21^{+8.68}_{-5.06}$	$4.59^{+4.33}_{-2.52}$
$\Xi_c^* \Sigma_c^* K^*$	$6.20^{+4.54}_{-2.88}$	$0.044^{+0.052}_{-0.026}$	$11.94^{+12.78}_{-6.81}$	$5.96^{+6.36}_{-3.40}$
$\Sigma_c^* \Sigma_c^* \rho$	$6.11^{+4.55}_{-2.71}$	$0.053^{+0.068}_{-0.033}$	$1.39^{+1.56}_{-0.76}$	$0.68^{+0.78}_{-0.36}$
$\Omega_b^* \Omega_b^* \phi$	$7.22^{+4.09}_{-3.00}$	$0.035^{+0.028}_{-0.017}$	$1.05^{+0.74}_{-0.46}$	$0.52^{+0.38}_{-0.22}$
$\Omega_b^* \Xi_b^* K^*$	$5.94^{+3.47}_{-2.45}$	$0.029^{+0.025}_{-0.014}$	$3.62^{+2.90}_{-1.79}$	$1.81^{+1.47}_{-0.92}$
$\Xi_b^* \Sigma_b^* K^*$	$5.65^{+4.07}_{-2.62}$	$0.037^{+0.035}_{-0.019}$	$4.41^{+3.94}_{-2.26}$	$2.20^{+1.97}_{-1.12}$
$\Sigma_b^* \Sigma_b^* \rho$	$5.30^{+3.95}_{-2.40}$	$0.044^{+0.044}_{-0.023}$	$0.48^{+0.43}_{-0.23}$	$0.24^{+0.22}_{-0.11}$
$\Omega_c^* \Omega_c^* \phi$	$6.80^{+2.33}_{-2.25}$	$0.036^{+0.022}_{-0.016}$	$2.50^{+1.26}_{-0.93}$	$1.24^{+0.63}_{-0.46}$
$\Omega_c^* \Xi_c^* K^*$	$6.05^{+1.89}_{-1.84}$	$0.034^{+0.020}_{-0.016}$	$9.21^{+6.05}_{-4.33}$	$4.59^{+3.02}_{-2.15}$
$\Xi_c^* \Sigma_c^* K^*$	$6.20^{+2.32}_{-2.14}$	$0.044^{+0.028}_{-0.021}$	$11.94^{+8.02}_{-5.64}$	$5.96^{+3.99}_{-2.82}$
$\Sigma_c^* \Sigma_c^* \rho$	$6.11^{+1.86}_{-1.79}$	$0.053^{+0.035}_{-0.026}$	$1.39^{+0.80}_{-0.55}$	$0.68^{+0.40}_{-0.26}$
$\Omega_b^* \Omega_b^* \phi$	$7.22^{+2.60}_{-2.35}$	$0.035^{+0.018}_{-0.013}$	$1.05^{+0.47}_{-0.34}$	$0.52^{+0.24}_{-0.16}$
$\Omega_b^* \Xi_b^* K^*$	$5.94^{+2.04}_{-1.84}$	$0.029^{+0.016}_{-0.010}$	$3.62^{+2.00}_{-1.47}$	$1.81^{+1.04}_{-0.77}$
$\Xi_b^* \Sigma_b^* K^*$	$5.65^{+2.25}_{-1.97}$	$0.037^{+0.020}_{-0.014}$	$4.41^{+2.49}_{-1.79}$	$2.20^{+1.24}_{-0.89}$
$\Sigma_b^* \Sigma_b^* \rho$	$5.30^{+1.91}_{-1.67}$	$0.044^{+0.023}_{-0.017}$	$0.48^{+0.23}_{-0.16}$	$0.24^{+0.11}_{-0.08}$
Average Values	6.16	0.039		

Table 1: The values of the strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 , the wide-hat $\hat{}$ denotes the uncertainties originate from the parameters λ_i are subtracted.

numerical results of the strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 , which are shown in the Table 1. We estimate the uncertainties δ with the formula $\delta = \sqrt{\sum_i \left(\frac{\partial f}{\partial x_i} \right)^2 |_{x_i=\bar{x}_i} (x_i - \bar{x}_i)^2}$, where the f denotes strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 , the x_i denotes the relevant parameters m_Q , $\langle \bar{q}q \rangle$, $\langle \bar{s}s \rangle$, \dots . In the numerical calculations, we take the approximation $\left(\frac{\partial f}{\partial x_i} \right)^2 (x_i - \bar{x}_i)^2 \approx [f(\bar{x}_i \pm \Delta x_i) - f(\bar{x}_i)]^2$ for simplicity. For the central values of the strong coupling constants, $\frac{|g_1 - \tilde{g}_1|}{\tilde{g}_1} < 20\%$, $\frac{|g_2 - \tilde{g}_2|}{\tilde{g}_2} < 40\%$, the heavy quark symmetry and the light-flavor $SU(3)$ symmetry work rather well.

From Table 1, we can see that the values of the \tilde{g}_3 and \tilde{g}_4 differ from each other greatly in different channels, it is no use to obtain an average. In the sum rules for the strong coupling constants \tilde{g}_3 and \tilde{g}_4 , the dominant contributions come from the two-particle twist-4 light-cone distribution amplitude $\tilde{A}(1 - u_0)$, the light-flavor $SU(3)$ symmetry breaking effects $m_s \pm m_q$ are too large, i.e.

$$\begin{aligned}
\tilde{\tilde{A}}(1 - u_0) &= 0.093, \quad \tilde{A}(1 - u_0) = 0.495, \quad A(1 - u_0) = 1.445, \\
\tilde{\tilde{A}}(1 - u_0) &= 1.121, \quad \tilde{A}(1 - u_0) = 3.356, \quad A(1 - u_0) = 1.581, \\
\tilde{\tilde{A}}(1 - u_0) &= 0.089, \quad \tilde{A}(1 - u_0) = 0.500, \quad A(1 - u_0) = 1.554,
\end{aligned} \tag{8}$$

for the vector mesons $\phi(1020)$, $K^*(892)$, $\rho(770)$, respectively; one can consult Ref.[43] for the lengthy expressions of the twist-4 light-cone distribution amplitude $A(u)$.

The main uncertainties originate from the parameters λ_i (g_1 , g_2 , \tilde{g}_3 and $\tilde{g}_4 \propto \frac{1}{\lambda_i \lambda_j}$) and m_Q , the variations of those parameters can lead to relatively large changes for the numerical values, and almost saturate the total uncertainties, i.e. the variations of the two hadronic parameters λ_i and λ_j lead to an uncertainty about $25\% \times \sqrt{2} = 35\%$, and the variations of the m_Q lead to an

uncertainty about $(10 - 20)\%$, refining those parameters is of great importance. In Table 1, we also present the values of the strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 with the uncertainties originate from the parameters λ_i are subtracted. On the other hand, although there are many parameters in the light-cone distribution amplitudes [42, 43], the uncertainties originate from those parameters are rather small.

Those strong coupling constants in the vertexes B^*B^*V are basic parameters in describing the interactions among the heavy mesons and heavy baryons, once reasonable values are obtained, we can use them to study the meson-baryon scatterings and perform other phenomenological analysis. In the present case, the values of the g_1 and g_2 are rather good, while the values of the \tilde{g}_3 and \tilde{g}_4 are not satisfactory, the two-particle twist-4 light-cone distribution amplitude $A(u)$ should be re-estimated.

4 Conclusion

The strong coupling constants in the vertexes B^*B^*V are basic parameters in describing the interactions among the heavy mesons and heavy baryons, where the flavor $SU(4)$ symmetry and the spin $SU(2)$ symmetry (or the flavor-spin $SU(8)$ symmetry) are badly broken, an universal coupling constant is not a good approximation. In this article, we parameterize the vertexes $\Omega_Q^*\Omega_Q^*\phi$, $\Omega_Q^*\Xi_Q^*K^*$, $\Xi_Q^*\Sigma_Q^*K^*$ and $\Sigma_Q^*\Sigma_Q^*\rho$ with four tensor structures due to Lorentz invariance, study the corresponding four strong coupling constants g_1 , g_2 , \tilde{g}_3 and \tilde{g}_4 with the light-cone QCD sum rules. In calculation, we order the Dirac matrixes as $\not{p}\not{p}\not{q}\not{q}$ and choose the tensor structures $\not{p}p\cdot\epsilon w\cdot z$, $\not{p}\not{q}p\cdot\epsilon w\cdot z$, $\not{p}p\cdot\epsilon q\cdot wq\cdot z$, $\not{q}p\cdot\epsilon q\cdot wq\cdot z$ to avoid the contaminations from the negative-parity heavy baryons states as the interpolating currents couple to both the spin-parity $J^P = \frac{3}{2}^+$ and $J^P = \frac{1}{2}^-$ states. The final numerical results indicate that the heavy quark symmetry and the light-flavor $SU(3)$ symmetry work rather well for the strong coupling constants g_1 and g_2 , while the values of the \tilde{g}_3 and \tilde{g}_4 differ from each other greatly in different channels. The dominant contributions to the strong coupling constants \tilde{g}_3 and \tilde{g}_4 come from the two-particle twist-4 light-cone distribution amplitude $\tilde{A}(1 - u_0)$, where the light-flavor $SU(3)$ symmetry breaking effects are too large and should be re-estimated. We can use the strong coupling constants g_1 and g_2 to study the dynamically generated molecule-like states via the meson-baryon scatterings or perform other phenomenological analysis.

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Appendix

The 32 sum rules for the strong coupling constants \tilde{g}_1 , \tilde{g}_2 , \tilde{g}_3 and \tilde{g}_4 in different channels,

$$\begin{aligned}
\tilde{g}_{\Omega_Q^* \Omega_Q^* \phi}^1 = & \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{f_\phi m_\phi \phi_{\parallel}(\bar{u}_0) M^4 E_1(x)}{2\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \right. \\
& - \frac{f_\phi m_\phi m_Q^2 \phi_{\parallel}(\bar{u}_0)}{36M^2} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} - \frac{f_\phi m_\phi^3 \tilde{A}(\bar{u}_0) M^2 E_0(x)}{8\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
& + \frac{f_\phi m_\phi^3 m_Q^2 \tilde{A}(\bar{u}_0)}{144M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{1}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
& - \frac{f_\phi m_\phi^3 \tilde{C}(\bar{u}_0)}{\pi^2} \int_0^1 dt \bar{t} [2M^2 E_0(x) + \tilde{m}_Q^2] e^{-\frac{\bar{m}_Q^2}{M^2}} \\
& - \frac{f_\phi m_\phi^3 m_Q^2 \tilde{C}(\bar{u}_0)}{18M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} \left[1 - \frac{\tilde{m}_Q^2}{M^2} \right] e^{-\frac{\bar{m}_Q^2}{M^2}} \\
& + \frac{\tilde{f}_\phi^\perp m_\phi^2 m_s h_s^\parallel(\bar{u}_0) M^2 E_0(x)}{2\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
& - \frac{\tilde{f}_\phi^\perp m_\phi^2 m_s m_Q^2 h_s^\parallel(\bar{u}_0)}{36M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{1}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} + \frac{f_\phi m_\phi \phi_{\parallel}(\bar{u}_0)}{72} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \Big\} \\
+ & \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - m_Q^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{\langle \bar{s}s \rangle f_\phi m_\phi m_s \phi_{\parallel}(\bar{u}_0)}{3} - \frac{2\langle \bar{s}s \rangle f_\phi m_\phi^3 m_s m_Q^2 \tilde{C}(\bar{u}_0)}{3M^4} \right. \\
& - \frac{\langle \bar{s}g_s \sigma G s \rangle f_\phi m_\phi m_s g_\perp^{(v)}(\bar{u}_0)}{18M^2} \left(1 + \frac{m_Q^2}{M^2} \right) - \frac{2\tilde{f}_\phi^\perp m_\phi^2 \langle \bar{s}s \rangle h_s^\parallel(\bar{u}_0)}{3} \\
& + \frac{\langle \bar{s}g_s \sigma G s \rangle f_\phi m_\phi^2 h_s^\parallel(\bar{u}_0)}{6M^2} \left(1 + \frac{m_Q^2}{M^2} \right) - \frac{f_\phi m_\phi^3 \tilde{C}(\bar{u}_0)}{36M^2} \langle \frac{\alpha_s GG}{\pi} \rangle + \frac{f_\phi m_\phi^3 \tilde{A}(\bar{u}_0)}{288M^2} \langle \frac{\alpha_s GG}{\pi} \rangle \Big\}, \tag{9}
\end{aligned}$$

$$\tilde{g}_{\Omega_Q^* \Omega_Q^* \phi}^2 = -\frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \frac{f_\phi^\perp m_\phi m_Q g_\perp^{(a)}(\bar{u}_0)}{144M^2} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{1}{t} e^{-\frac{\bar{m}_Q^2}{M^2}}, \tag{10}$$

$$\begin{aligned}
\tilde{g}_{\Omega_Q^* \Omega_Q^* \phi}^3 &= \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{2u_0 f_\phi m_\phi \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right] M^2 E_0(x)}{\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \right. \\
&\quad - \frac{u_0 f_\phi m_\phi m_Q^2 \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right]}{9M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad - \frac{u_0 f_\phi m_\phi^3 \tilde{A}(\bar{u}_0)}{2\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} + \frac{u_0 f_\phi m_\phi^3 m_Q^2 \tilde{A}(\bar{u}_0)}{36M^6} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{1}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad + \frac{2u_0^2 f_\phi m_\phi^3 \tilde{C}(\bar{u}_0)}{\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} - \frac{u_0^2 f_\phi m_\phi^3 m_Q^2 \tilde{C}(\bar{u}_0)}{9M^6} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad \left. + \frac{u_0 f_\phi m_\phi \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right]}{18M^2} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt e^{-\frac{\bar{m}_Q^2}{M^2}} \right\} \\
&+ \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - m_Q^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{4u_0 \langle \bar{s}s \rangle f_\phi m_\phi m_s \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right]}{3M^2} \right. \\
&\quad \left. + \frac{4u^2 \langle \bar{s}s \rangle f_\phi m_\phi^3 m_s \tilde{C}(\bar{u}_0)}{3M^4} - \frac{u_0 f_\phi m_\phi^3 \tilde{A}(\bar{u}_0)}{72M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \right\}, \tag{11}
\end{aligned}$$

$$\begin{aligned}
\tilde{g}_{\Omega_Q^* \Omega_Q^* \phi}^4 &= \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{2u_0^2 f_\phi m_\phi \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right] M^2 E_0(x)}{\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} \right. \\
&\quad - \frac{u_0^2 f_\phi m_\phi m_Q^2 \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right]}{9M^4} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad - \frac{u_0^2 f_\phi m_\phi^3 \tilde{A}(\bar{u}_0)}{2\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} + \frac{u_0^2 f_\phi m_\phi^3 m_Q^2 \tilde{A}(\bar{u}_0)}{36M^6} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{1}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad + \frac{2u_0^3 f_\phi m_\phi^3 \tilde{C}(\bar{u}_0)}{\pi^2} \int_0^1 dt \bar{t} e^{-\frac{\bar{m}_Q^2}{M^2}} - \frac{u_0^3 f_\phi m_\phi^3 m_Q^2 \tilde{C}(\bar{u}_0)}{9M^6} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt \frac{\bar{t}}{t^2} e^{-\frac{\bar{m}_Q^2}{M^2}} \\
&\quad \left. + \frac{u_0^2 f_\phi m_\phi g_\perp^a(\bar{u}_0)}{72M^2} \langle \frac{\alpha_s GG}{\pi} \rangle \int_0^1 dt e^{-\frac{\bar{m}_Q^2}{M^2}} \right\} \\
&+ \frac{1}{\lambda_{\Omega_Q^*}^2} \exp \left[\frac{M_{\Omega_Q^*}^2 - m_Q^2 - u_0 \bar{u}_0 m_\phi^2}{M^2} \right] \left\{ \frac{4u_0^2 \langle \bar{s}s \rangle f_\phi m_\phi m_s \left[\tilde{\phi}_\parallel(\bar{u}_0) - \tilde{g}_\perp^{(v)}(\bar{u}_0) \right]}{3M^2} \right. \\
&\quad \left. + \frac{4u^3 \langle \bar{s}s \rangle f_\phi m_\phi^3 m_s \tilde{C}(\bar{u}_0)}{3M^4} \right\}. \tag{12}
\end{aligned}$$

With the simple replacements,

$$\begin{aligned}
\tilde{g} &\rightarrow 2\tilde{g}, \lambda_{\Omega_Q^*}^2 \rightarrow \lambda_{\Omega_Q^*} \lambda_{\Xi_Q^*}, M_{\Omega_Q^*}^2 \rightarrow \frac{M_{\Omega_Q^*}^2 + M_{\Xi_Q^*}^2}{2}, f_\phi \rightarrow f_{K^*}, f_\phi^\perp \rightarrow f_{K^*}^\perp, m_\phi \rightarrow m_{K^*}, \\
\tilde{g} &\rightarrow 2\tilde{g}, \lambda_{\Omega_Q^*}^2 \rightarrow \lambda_{\Sigma_Q^*} \lambda_{\Xi_Q^*}, M_{\Omega_Q^*}^2 \rightarrow \frac{M_{\Sigma_Q^*}^2 + M_{\Xi_Q^*}^2}{2}, f_\phi \rightarrow f_{K^*}, f_\phi^\perp \rightarrow f_{K^*}^\perp, m_\phi \rightarrow m_{K^*}, \\
&\langle \bar{s}s \rangle \rightarrow \langle \bar{q}q \rangle, \langle \bar{s}g_s \sigma Gs \rangle \rightarrow \langle \bar{q}g_s \sigma Gq \rangle, m_s \rightarrow m_q, \\
\tilde{g} &\rightarrow 2\tilde{g}, \lambda_{\Omega_Q^*}^2 \rightarrow \lambda_{\Sigma_Q^*}^2, M_{\Omega_Q^*}^2 \rightarrow M_{\Sigma_Q^*}^2, f_\phi \rightarrow f_\rho, f_\phi^\perp \rightarrow f_\rho^\perp, m_\phi \rightarrow m_\rho, \langle \bar{s}s \rangle \rightarrow \langle \bar{q}q \rangle, \\
&\langle \bar{s}g_s \sigma Gs \rangle \rightarrow \langle \bar{q}g_s \sigma Gq \rangle, m_s \rightarrow m_q,
\end{aligned} \tag{13}$$

we can obtain the corresponding strong coupling constants in the vertexes $\Omega_Q^* \Xi_Q^* K^*$, $\Xi_Q^* \Sigma_Q^* K^*$, $\Sigma_Q^* \Sigma_Q^* \rho$, respectively. Here $\bar{u}_0 = 1 - u_0$, $\tilde{f}_\phi = f_\phi - f_\phi^\perp \frac{2m_s}{m_\phi}$, $\tilde{f}_\phi^\perp = f_\phi^\perp - f_\phi \frac{2m_s}{m_\phi}$, $\tilde{f}_{K^*} = f_{K^*} - f_{K^*}^\perp \frac{m_u+m_s}{m_{K^*}}$, $\tilde{f}_{K^*}^\perp = f_{K^*}^\perp - f_{K^*} \frac{m_u+m_s}{m_{K^*}}$, $\tilde{f}_\rho = f_\rho - f_\rho^\perp \frac{m_u+m_d}{m_\rho}$, $\tilde{f}_\rho^\perp = f_\rho^\perp - f_\rho \frac{m_u+m_d}{m_\rho}$, $M_1^2 = M_2^2 = 2M^2$ and $u_0 = \frac{M_1^2}{M_1^2 + M_2^2} = \frac{1}{2}$ as $\frac{M_i^2}{M_i^2 + M_j^2} \approx \frac{1}{2}$, $\tilde{m}_Q^2 = \frac{m_Q^2}{t}$, $E_n(x) = 1 - (1 + x + \frac{x^2}{2!} + \dots + \frac{x^n}{n!})e^{-x}$, $x = \frac{s_0}{M^2}$; $\tilde{f}(\bar{u}_0) = \int_0^{u_0} du \int_0^u dt f(1-t)$, $\tilde{f}(\bar{u}_0) = \int_0^{u_0} du f(1-u)$, the $f(u)$ denote the light-cone distribution amplitudes, the lengthy expressions of the light-cone distribution amplitudes $\phi_\parallel(u)$, $\phi_\perp(u)$, $A(u)$, $A_\perp(u)$, $g_\perp^{(v)}(u)$, $g_\perp^{(a)}(u)$, $h_\parallel^{(s)}(u)$, $h_\parallel^{(t)}(u)$, $h_3(u)$, $g_3(u)$, $C(u)$, $B_\perp(u)$, $C_\perp(u)$ can be found in Refs.[42, 43],

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